Resection of Arteries and Veins Injured in Continuity— End-to-End Suture

EXPERIMENTAL AND CLINICAL RESEARCH

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RESECTION OF ARTERIES AND VEINS INJURED IN CONTINUITY—END-TO-END SUTURE—EXPERIMENTAL AND CLINICAL RESEARCH.

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THE idea of suturing an artery after it had been injured was conceived by Lembert, and a case is reported by Broca from 1762 in which suture of a longitudinal incision of an artery was successfully made. Assmann in 1773 treated of it in a dissertation at Gröningen. The latter made two experiments on animals; both resulted unfavorably through an obliterating endarteritis. He then abandoned the work. Henry Lee, of London, in 1865 made some experiments with puncture to ascertain how large an opening could be made without fatal hemorrhage, and described the method of repair in arteries without suture; Beale made an extensive microscopic examination of Lee's specimens, giving the pathologic histology of repair.[1] In 1883 Gluck reported nineteen experiments with arterial suture, but in all of these cases his efforts were futile, because he was unable to control the hemorrhage from the needle punctures through which the suture was introduced. He also devised aluminium and ivory clamps for the purpose of uniting longitudinal incisions in the vessel, and succeeded with the ivory clamp in one experiment on the femoral of a large dog.[2] Von Horoch, of Vienna, had thrombosis in six experiments, including one end-to-end union (1887). The most extensive and indeed the only work of true merit performed in this line was by Dr. Alexander Jassinowsky, of Odessa. His first paper was read in Dorpat in 1889; his second was published in *Langenbeck's Archiv*, 1891. Bruci in 1889 sutured six longitudinal incisions in arteries of dogs, and was successful in four. Tansini, of Modena, in 1890 endeavored to close the arteries by absorbable horn clamps. Muscatello successfully sutured a one-third division of the abdominal aorta in a dog. Heidenhain, May 28, 1894, closed by catgut suture an opening in the axillary artery one centimetre long, which was accidentally made while removing adherent carcinomatous glands. The patient made a good recovery; circulation in the extremity was not disturbed. In the same year, 1894, Robert Abbe made some very interesting and instructive experiments, placing sterilized glass tubes in vessels with the intention of uniting them and re-establishing the circulation.[3] Von Zoege-Manteuffel in April, 1895, operated on an arterio-venous aneurism in Scarpa's triangle. He wounded the common femoral and made a successful lateral suture of the wall.[4] J. Israel, in discussing Gluck's paper, mentioned that he had closed the common iliac, which had been torn for two-thirds of its circumference in an operation for a perityphlitic abscess, by inserting five fine silk sutures through the entire wall of the vessel.[5] It

[1] The Transactions of the Medico-Chirurgical Society, vol. L., p. 477.
[2] Langenbeck's Archiv, 1883.
[3] New York Medical Journal, January 13, 1894.
[4] Berliner klin. Woch., No. 34, 1895.
[5] Berliner Cent. für Chir., December 7, 1895.

does not seem possible from my observations experimentally, that two-thirds of the circumference of a vessel of the size of the common iliac could be closed with five sutures and have the seam blood proof. Heidenhain endeavored to accomplish the closure of arterial wounds in the carotid of dogs by suture but failed. Sabanyeff, of Odessa, successfully closed a small opening in the femoral artery with suture, in 1896. Billroth, Schede, Braun, of Koenigsberg, Schmidt, and others successfully sutured wounds in veins, and the closure of wounds in veins by suture is now an accepted surgical procedure. I recently closed an opening three-eighths of an inch long in the common jugular with five continuous silk stitches. Small openings in veins have frequently been closed with lateral ligature. I cannot find recorded a case in which an artery has been sutured after complete division.

For the purpose of determining whether this were practicable, and whether a considerable portion of the artery could be resected, I have performed the following experiments:

Experiment No. 1.—March 4, 1896; male dog, weight forty pounds. An oblique incision dividing one-third of the circumference of the left common carotid was made and closed with a continuous silk suture penetrating all the coats of the artery; only a small portion of the artery was denuded. There was some hemorrhage from needle punctures after the clamps were removed, which subsided rapidly under digital pressure; the wound was closed. The dog showed no unpleasant symptoms after the operation. There was a slight swelling on the left side, which lasted about a week.

Post-mortem, March 25th, twenty-one days after operation: There was some new-formed connective tissue at the seat of operation. The sutures were not infected; the calibre of the vessel was only slightly diminished. The silk was covered and could be seen under a thin layer of exudate from the inner side of the vessel. There was no thrombus. The intima had been fractured by one of the clamps, at which point it was rough and somewhat thickened.

Experiment No. 2.—March 4, 1896; dog, weight fifty pounds. The right common carotid was exposed and opened by a longitudinal incision of one-third of an inch. The opening was closed by interrupted sutures involving all the coats. There was some hemorrhage after the clamps were removed, which ceased after a digital pressure of two minutes' duration. The external wound was closed with silkworm gut.

Post-mortem was made March 25th, twenty-one days after operation. There was considerable exudate around the position of sutures, but the sutures were not infected. The wall of the vessel was thickened on the side of the suture. The calibre of the vessel was diminished one-third; the suture was not exposed in the vessel; it was covered with a deposit. There was no thrombus. There was some roughening of the intima at the position where the clamps had been placed.

Experiment No. 3.—March 7, 1896; hunting-dog, weight about fifty pounds. The left femoral was exposed and an incision one-half inch long was made in its wall; it was closed with a continuous silk suture; vessel one-eighth inch in diameter. The vessel was clamped with eight-inch Billroth forceps covered with rubber, care being taken not to compress the artery sufficiently to injure the intima. There was no difficulty in producing an accurate approximation of the margins of the wound with silk sutures. A very slight hemorrhage took place through the needle holes after the clamps were removed, which ceased in less than a minute. The external wound was closed with silkworm gut.

Examination of left femoral, March 15th, eight days after operation:

Union, no hemorrhage, no suppuration; the vessel was completely thrombosed.

Experiment No. 4.—Same day, same dog. Invagination of right femoral after complete division. Two double-needled silk sutures were used to draw the intussusceptum one-third of an inch into the intussuscipiens, as shown in Fig. 1. Several interrupted sutures bind the end of the intussuscipiens to the circumference of the intussusceptum (Fig. 2).

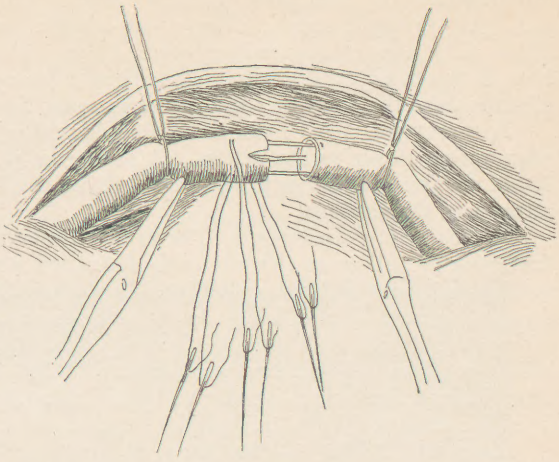

Fig. 1.—Shows Method of Inserting Sutures to Produce Invagination.

Examination, March 15th, eight days after operation: There had been no hemorrhage from the vessel. A slight infection had taken place around the seat of operation. The artery was thrombosed.

Microscopic examination showed the lumen filled with a red thrombus and the wall to consist of two distinct muscular layers, both diffusely infiltrated with round cells. The lumen was very small and the wall very thick.

Experiment No. 5.—March 11, 1896; dog, weight sixty pounds. Large head and neck. Resection of three-fourths of an inch of right common carotid. The proximal end was invaginated with three silk sutures; several sutures penetrating the adventitia and media were used to secure the end of the intussuscipiens to the periphery of the intussusceptum. The sheath was sewed over the vessel. The adventitia was separated from the media on either end. The Billroth clamp forceps were used to suppress the hemorrhage.

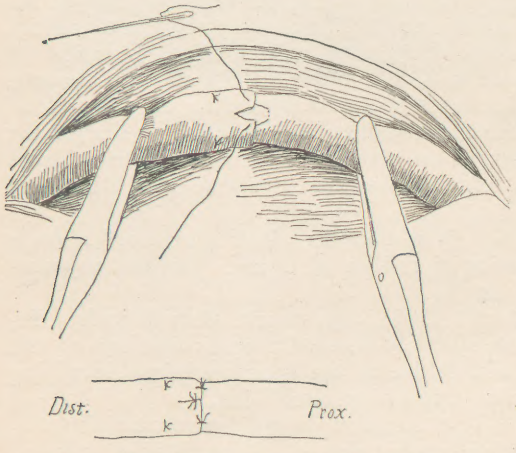

Fig. 2.—Shows Method of Inserting External Sutures.

Post-mortem, April 15th, thirty-five days after operation: Some periarteritis and adhesions existed. The sutures in the skin had suppurated. The area around the vessel was not infected; there was but little contraction at the position of approximation.

Microscopic examination: There was some thickening in the wall. The thickening in the media was more pronounced than in the intima; the process was not progressive. There was nothing to indicate that the artery would not have remained patulous. The wall of the artery showed no evidence of injury by the clamps.

EXPERIMENT No. 6.—March 11, 1896; left common carotid in same dog as in Experiment No. 5. Resection of one-half inch of artery. End-to-end suture without invagination. The suture penetrated all the coats; it was continuous and contracted the artery considerably at the line of approximation. It was made with two needles on one thread and a continuous figure-of-eight stitch. There was a little hemorrhage from the needle-holes after the sutures were placed. This subsided under a sponge pressure of two minutes' duration. The sheath was not sutured around the vessel. Clamps were the same as used in Experiment No. 5.

Post-mortem, April 15th, thirty-five days after operation. The wound was suppurating down to the artery. A pocket of pus existed deep in the neck. All of the arterial sutures were exposed in the bottom of the wound. The artery was thrombosed.

Microscopic examination: The artery presented just the opposite condition from its fellow on the left side, described above. The intima was very much thickened and was rapidly obliterating the tube. The histology was that of organization of clot; connective-tissue cells and blood-vessels were taking the place of coagulated blood. The media was likewise somewhat inflamed. There was some inflammation along the lymphatics and adventitia, and there were numerous foci of infection. The case was a typical infective endarteritis with formation of coagulum.

EXPERIMENT No. 7.—March 15, 1896; dog, weight forty pounds. Longitudinal incision in the right iliac, five-eighths of an inch in length, was closed with a continuous silk suture including all of the coats of the artery. Five days after the operation a very marked swelling appeared at the position of suture and blood began to ooze from the line of union. The dog was again anæsthetized, the cutaneous sutures were removed, the margins of the wound were separated. A decomposed clot about the size of a hen's egg was carefully elevated. There was an absence of union of the wall of the vessel, and when the clot was removed profuse hemorrhage ensued. A ligature was placed above and below the incision in the artery and that portion of the vessel excised. The cause of the non-union of the vessel in this case, I believe, was infection. There was no clot in the artery.

EXPERIMENT No. 8.—March 18, 1896; dog, weight thirty pounds. A longitudinal incision one-half inch long was made in the abdominal aorta, which was closed with a continuous silk suture including all the arterial coats. A slight hemorrhage occurred through needle punctures after the clamps were removed, which ceased on one and one-half minutes' digital pressure. No effort was made to cover the line of suture with adventitia or peritoneum.

The dog died March 28th. Post-mortem: Retroperitoneal abscess around artery. Complete occlusion of calibre of artery. General suppurative peritonitis was the cause of death.

EXPERIMENT No. 9.—March 26, 1896; dog, weight sixty pounds. Invagination of left carotid by three double-needled threads attached to the intussusceptum and interrupted silk suture of the intussuscipiens involving only the tunica adventitia and media of the proximal side.

Post-mortem, April 25, 1896: Left common carotid surrounded by considerable exudate with suppuration around one of the cutaneous stitches. A small sinus led down to one of the sutures at the position of approximation. The vessel wall was considerably thickened at the line of union, as shown in Fig. 3. The vessel admitted a considerable stream of water through it immediately after its removal. It was somewhat dilated on the proximal side. The collateral branches were enlarged.

Microscopic examination: Most evidence of endarteritis at 3 and 4 (Fig. 3). Much of the tissue between 2 and 5 seemed accidental. The invaginated walls could be outlined, but the line of demarcation between them was scarcely discernible. The connective tissue around the artery showed a large number of blood-vessels and a cross section of a nerve of considerable size. There was a small amount of inflammation of the vascular and lymph channels at that point. In the adventitia there was a violent acute inflammatory process, with foci which resembled those of suppuration. The showing in the media was the same as in the right carotid. In the intima the process was still more violent. The inner elastic lamina was so broken up as to be unrecognizable.

Experiment No. 10.—Same dog as in Experiment No. 9, same day. Resection of one-half inch of right carotid. Adventitia peeled back. Three double-needled sutures were attached to the intussusceptum and put through

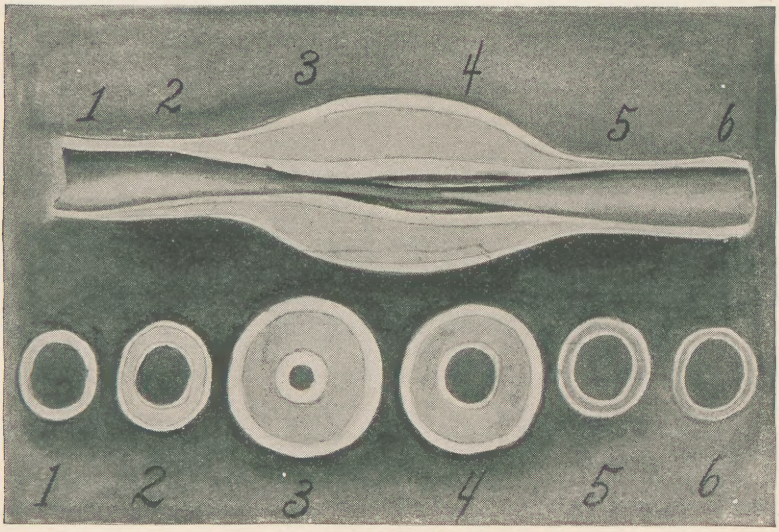

Fig. 3.—Shows the Diminution of Lumen of the Vessel with Thickening of the Wall, from Experiment No. 9.

the intussuscipiens from within outward, invaginating the intussusceptum one-third inch; then sutured the intussuscipiens to the periphery of the intussusceptum, as shown in Fig. 2. The sheath of the artery was sewed around it; the adventitia was not sutured.

Post-mortem on right carotid, April 25th, showed no suppuration around the artery; considerable inflammatory exudate; artery enlarged at position of invagination, as shown in Fig. 4. Nerve and vein involved in exudate. Vessel admitted a stream of water about one-half its normal diameter. It was enlarged on the proximal side of the union.

Microscopic examination showed marked evidence of endarteritis. The line just below 3, Fig. 4, indicates suture. At 2 much exudate, but less than at 3. At 4 the lumen is about one-half as large as it is at 1 and 5. The lumen at 3 is one-half of what it is at 5. Most of the tissue between 2 and 5 is foreign. There is a moderate amount of inflammation in the adventitia and a large number of new blood-vessels. Muscle fibres of the media

alternate with bands of small round cells. Capillaries in the outer walls are apparent. The region of the intima is the seat of a very marked round-celled infiltration; capillaries can be seen in this coat. The thickness of the intima is markedly increased and the lumen is about one-third of the normal size. There are no endothelia lining the intima. Another section presents the same appearance, except that what remains of the lumen is a triangular opening. There are sections of nerves in the loose tissue surrounding the vessel.

It will be noticed that notwithstanding the invagination had been made thirty days previous to the post-mortem there was no clot in the vessel, and the diameter of the lumen was one-third of that above and below the point of union, showing that the endarteritis had progressed slowly.

Experiment No. 11.—April 26, 1896; calf, six weeks old. Excision of one-third inch of left common carotid. Invagination of all coats of

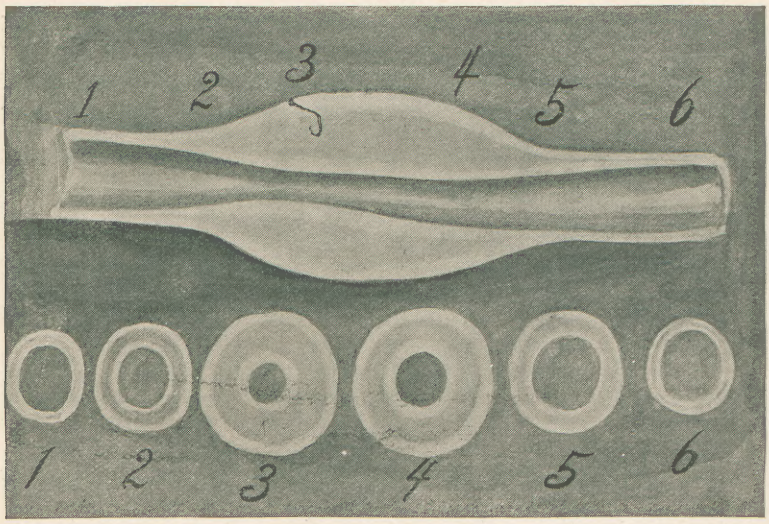

Fig. 4.—Shows the Thickening of the Arterial Wall and Diminution of the Lumen of the Vessel, from Experiment No. 10.

proximal into distal end for three-eighths of an inch. The artery was clamped with Billroth forceps. It was found to be elastic and free from tension when replaced. Peripheral sutures were used to secure the invaginated portion, as described above. There was little hemorrhage after the operation was completed. The sheath was sewed around the artery. There was a tumor around the area of approximation with considerable swelling for three weeks after the operation, which disappeared almost entirely before the specimen was removed for examination.

Specimen secured June 1st, thirty-four days after operation; one and one-half inches of carotid at point of suture were removed and the ends ligated. There was considerable inflammatory deposit over the entire field of operation. The union of skin was complete. The collateral vessels around the position of approximation were considerably enlarged. The vessel was not patulous, the lumen being filled by a clot for a considerable space on the distal side of approximation; it extended but one-fourth of an inch on the proximal side.

Microscopic examination showed on the outside a loose layer of connective tissue, the fibres of which did not run in any particular direction. Internal to this was a layer of felted connective-tissue interlacing and a very rich supply of blood-vessels, richer than is normal in the adventitia. Most of these fibres were of the yellow elastic variety and interlaced in the general trend of the artery. Internal to the adventitia was the tunica media, consisting of muscular fibres, elastic tissue, and a great abundance of inflammatory cells. Internal to this was the inner elastic lamina. Within this there was a zone which at some of the points of its circumference was composed of mature connective-tissue fibres; at others it consisted of a pool of blood. Internal to this was a dense mass of muscle fibres. The fibres of the media were swollen and granular and not in a good state of nutrition. Internal to this was the inner elastic lamina of the invaginated portion of the artery and the lumen of the tube was filled with a clot. There was some evidence of connective-tissue growth in this clot. The union between the artery ends was incomplete.

Experiment No. 12.—Right common carotid of calf, same as used in Experiment 11. Operated May 3, 1896. Resection of one-half inch of artery, united with three invaginating sutures. Three peripheral sutures were made as above; but very little bleeding followed the operation. Sheath was drawn over artery. Clamps used as temporary hæmostatics. The skin was approximated with catgut. There was no swelling or tumefaction after operation, as on opposite side.

June 1, 1896, one inch of artery at point of union was removed and artery was again sutured (see Experiment 13). But little inflammatory deposit was found around the seat of wound. Primary union of skin and subcutaneous tissue had taken place. Some reactive inflammation had taken place around the artery. Water passed freely through the artery when removed.

Microscopic examination: The section showed a mass of granulation tissue older at the periphery than at the centre. The inflammation was somewhat nodular; there were some places where it was more intense than at others. In the centre there was a small opening, in the walls of which there were young embryonal cells. The artery was being obliterated by a general arteritis.

Experiment No. 13.—June 1, 1896, the second experiment on right common carotid of calf. In the first experiment of May 3d one-half inch of artery was removed. On June 1st the specimen was removed, one inch being taken out at seat of union. The artery was then sutured end-to-end with interrupted silk sutures, without invagination. There was some tension on the sutures and the artery was somewhat diminished in size. The left carotid had previously been removed and the ends ligated. When the clamps were taken off there was no hemorrhage at the line of suture. The calf rallied after the operation and was perfectly well.

Post-mortem, June 5th, four days after operation: Primary adhesion of wound; the artery was carefully dissected out. There had been no hemorrhage around the line of union; the vessel was patulous; its lumen was slightly diminished. A small white exudate covered the line of union. The sutures were not exposed in the lumen of the artery, being covered by the exudate. The intima had not been fractured at the point where the clamps were placed.

Experiment No. 14.—August 26, 1896; brown dog, weight forty pounds. Median abdominal incision. The abdominal aorta was located just above its iliac bifurcation and exposed for two inches. Billroth clamps

were placed in position. A transverse incision was made in the artery for two-fifths of its circumference. It was sutured with kangaroo tendon involving all the coats. There was some hemorrhage after removal of the clamps. An additional superficial suture was inserted. The retro-abdominal peritoneum was closed over the artery. The abdominal wound was closed with silkworm gut sutures. The dog died three days after operation.

Post-mortem: Abdominal cavity filled with blood; no peritonitis. An opening was found in the posterior abdominal peritoneum leading to the vessel. The vessel was removed. A clot of considerable size existed in the retroperitoneal space around the opening of the vessel; this was continuous with a small clot within the vessel shown in gelatin specimen No. 2 (Fig. 5). The clot on the inner side of the vessel measured three-eighths of an inch in length and one-eighth of an inch in diameter. It was not adherent to the wall of the vessel but was continuous with the clot from the outside. There

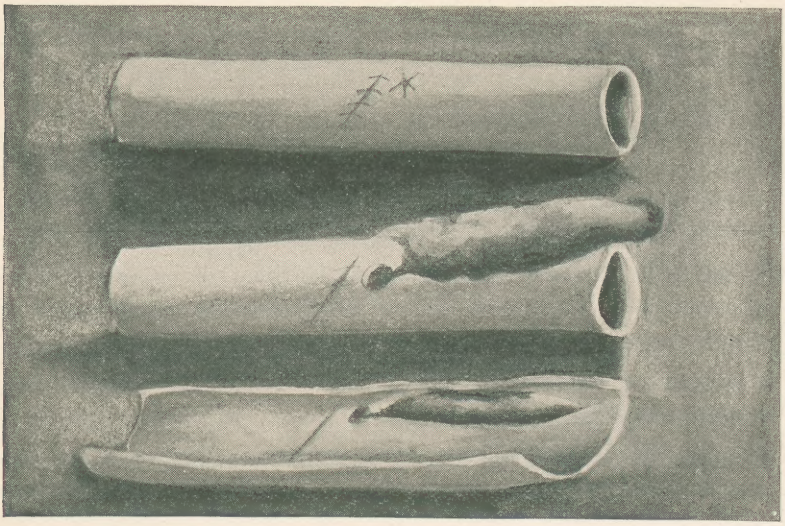

FIG 5.—Shows the Line of Suture and the Formation of Internal and External Coagulum in Experiment No. 14.

was some discoloration of the intima from the upper clamp and a roughening of the surface at that point, but no clot was formed. The lumen of the artery above and below the suture was free. The kangaroo tendon was softened and would not support its own weight, which accounted for the hemorrhage. On the inner surface of the artery were seen the openings of the small arteries, which were free. There was a ragged transverse opening, which was gaping widely at the centre. The point of adhesion of the clot was without the arterial wall. The remnants of the sutures were seen penetrating the intima. One and one-half centimetres above there was a point of ecchymosis. One centimetre above that a second point of ecchymosis could be seen, the result of the clamps. The ecchymotic patches were transverse in their long diameter and three-fifths centimetres wide. In the one next to the incision there had been rupture of the deep arterial coats, but the intima had been preserved except at one small point; in the other fracture of the intima and media had taken place. There was no clot at either of these places (see Fig. 6).

Experiment No. 15.—Black dog, weight forty pounds. Operated August 26, 1896. Median abdominal incision. Exposure of abdominal aorta two inches above its iliac bifurcation. A longitudinal incision was made in the artery one centimetre in length. Sutured with kangaroo tendon taken from same bottle as for Experiment 14. Arterial clamps were placed on artery, as above. Slight hemorrhage from the wound after the clamps were removed. This was controlled by digital pressure for one minute. Posterior peritoneum was not sutured over artery. A great deal of difficulty was experienced in retaining the artery in an elevated position sufficient to admit of suture, as the dog was fat and his abdomen deep. The dog died forty-eight hours after operation.

Post-mortem: Abdomen full of blood. Loose large clot existed in retroperitoneal space. The artery was removed for several inches above and below the clot; its lumen was free. There was no clot on the inner

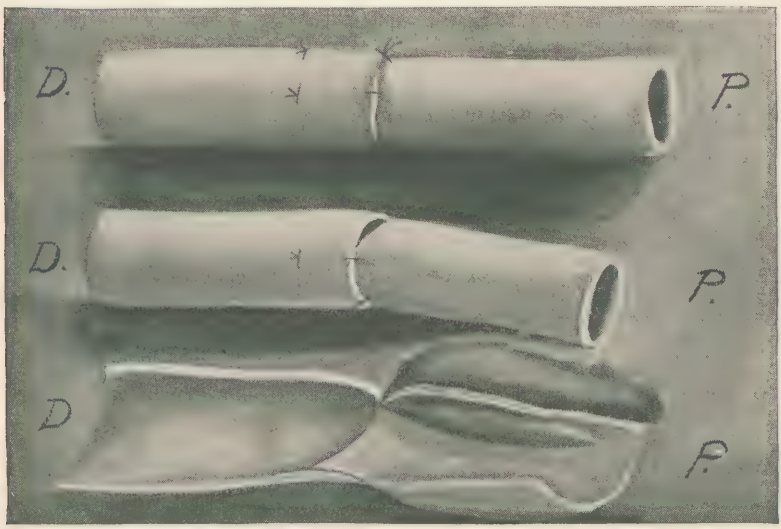

Fig. 6.—Shows Perforation of Artery and Line of Union after Removal of Clot in Experiment No. 14.

side. The kangaroo tendon was completely disintegrated. Cause of death, hemorrhage.

The general appearance of the artery was normal. Small arteries were seen emerging at different points. The line of incision could be readily recognized. Its edges were roughened and projected about one millimetre into the lumen of the vessel. The ragged incision extended throughout the wall of the artery; in it were seen the remains of the tendon suture. There was no evidence of regeneration; that is, no reaction process in the walls of the vessel. There was some fibrinous deposit on the roughened edges; no tendency to coagulation on the inner side of the artery. About one centimetre below the line of incision was a small ecchymosis where the intima was roughened and endothelia absent; there was also a loss of substance, showing a fracture of the intima. There was a small fibrinous deposit on this area.

Experiment No. 16.—September 6, 1896; black male dog, weight seventy pounds. Transverse incision dividing one-half of the anterior wall of the abdominal aorta; the opening was closed by a continuous suture of silk

with round needle involving all the coats of the artery. After the clamps were removed there was bleeding from the angle of the wound; an additional suture was applied without the aid of the clamps. After this was done the bleeding ceased and the abdominal wound was closed. The dog died fifty-four hours after operation.

Post-mortem revealed the abdomen full of blood. An examination of the artery showed three-fourths of the line of suture approximated and surrounded by a clot. The last suture which was inserted in the angle of the wound was shown to have included on one side only the tunica adventitia, it did not grasp the media nor the intima. This suture gave way and from this point hemorrhage took place. There was no regenerative reaction in the intima around the punctures made by the needle. There was no clot formed on the silk that was exposed in the lumen of the vessel. From the ragged edge at the position of penetration a small clot was adherent and suspended

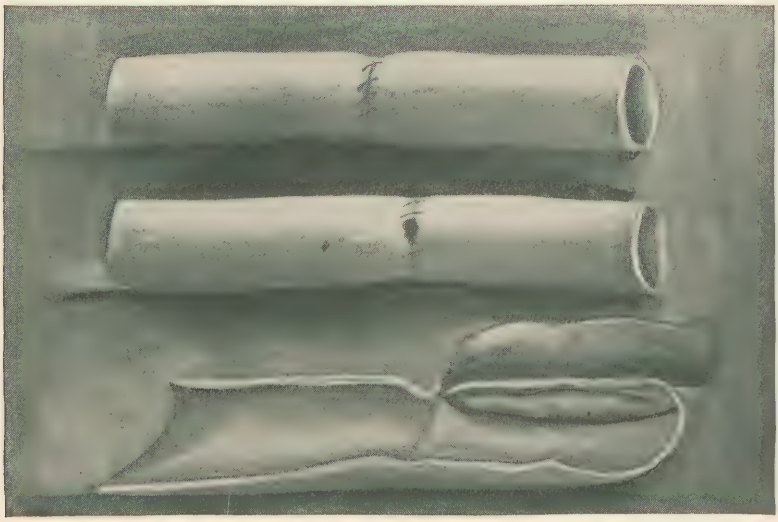

Fig. 7.—Shows the Position of Sutures in Edge-to-Edge Union of End of Artery and Defect in Line of Suture in Experiment No. 6.

within the artery, but not adherent to the intima; it was continuous with the external clot. This clot was about a centimetre in length and a millimetre in thickness; smooth on its outer edge. The endothelium in the immediate neighborhood was milky white and somewhat roughened.

Experiment No. 17.—September 6, 1896; black and white female dog, weight forty-five pounds. Complete transverse section of abdominal aorta. Continuous silk suture with three needles; edge-to-edge union of artery (Fig. 7). The stitches were closely applied. After the clamps were removed free hemorrhage took place, particularly at one point, where the beginning and end of the sutures met. The clamps were reapplied and one stitch was placed at this point. It would have been better if I had made the final stitch overlap the primary stitch, as the artery was contracted when the arterial pressure was off; while the first and last stitches appeared to be close together then, when the artery dilated they were quite a distance apart. The abdominal wall was closed with silkworm gut.

The dog died September 12th. Post-mortem showed silkworm gut to have

cut through; absence of organic union over entire length of abdominal incision. An external fistula communicated with the peritoneal cavity. The peritoneal cavity contained a large quantity of pus and some blood. There were many adhesions and a clot of considerable size around the iliac vessels. A clot also existed on the right side of the incision behind the iliac vessels. On the inner side of the artery the clot was adherent and sealed over the line of union. The clot was not adherent to the intima but adherent to the line of union. A slight thin white clot had formed over the point where the temporary hæmostatic forceps were placed during the operation. There were no manifestations of inflammatory reaction or regeneration in the intima; a small thin clot extended from the point of injury by the hæmostatic forceps above down to the line of union. A small flat coagulum extended from the line of union down to the injury of the intima made by the lower hæmostatic forceps. On the outside of the point where the hemorrhage took place the sutures were exposed. An opening one-sixteenth of an inch existed on the anterior surface of the vessel at the line of union communicating with its calibre and was partially occluded by a clot. This was the opening through which the fatal hemorrhage occurred. There was excellent union over the line of approximation. There was no clot in either of the iliac vessels. The intima was somewhat roughened over the entire distance between the position of application of both of the forceps. One of the stitches from the point where the hemorrhage occurred had cut through. There was a small perivascular clot around the position of approximation, and blood had burrowed between the tunica intima and media.

Experiment No. 18.—September 6, 1896; black dog, weight sixty-five pounds. Complete transverse section of abdominal aorta. Invagination of proximal into distal end with three internal sutures; eight external interrupted sutures were inserted, including all of the coats of the artery in each. When the clamps were removed profuse hemorrhage took place from one point. Clamps were replaced and an additional suture was inserted; the clamps were again removed, with no escape of blood. Abdominal wound closed with interrupted catgut sutures. On the sixth day after operation there was some bleeding through abdominal wound.

Dog died on the eighth day. Post-mortem: General suppurative peritonitis; a complete thrombosis of the artery had taken place at the site of suture. There was some blood in the peritoneal cavity; suppuration around the seat of arterial approximation. Two of the sutures had cut through. A thrombus occupied the vessel for two centimetres above the seat of injury, and two and one-half centimetres below; that is, between the points where the arterial clamps had been placed. The clot was adherent at these points and free in the vessel over the intermediate area.

Microscopic examination: A clot had formed, completely filling the lumen of the vessel. The surface of the clot was filled with round cells and developing connective tissue. The connective tissue developed from the intima in such a manner as to map the clot off into plaques of round cells mingled with leucocytes, and connective-tissue cells surrounded by borders of connective tissue. The intima was markedly thickened, the fibres being separated by bands of young connective-tissue cells. The spaces between the fibres filled with cells were broader than the fibres themselves. The same was the case in a lesser degree in the media and adventitia. Union had not progressed very far; it was not firm and tore apart upon slight manipulation. The granulation tissue by which it was held together was in the round-cell stage.

Experiment No. 19.—October 27, 1896; merino sheep, weight ninety

pounds. Transverse incision of left common carotid artery. Compression of artery with strands of gauze. Proximal invaginated into distal end in the usual manner. Four needles threaded with silk were used. After compression there was some hemorrhage; as one of the sutures had cut through the wall of the artery, another suture was inserted in its place. The artery was very small for invagination.

The sheep died twenty-eight hours after operation, from cerebral anæmia. See Experiment 20. Post-mortem: In the left common carotid artery the line of suture was scarcely discernible, it being covered with a cleavage; there was a very small clot on proximal side of suture (Fig. 8). There was injury to the intima by the peripheral sutures. Clot on distal side was not adherent except at position of approximation. Clot on proximal side extended beyond the position of division of the artery one-third inch from the point of approximation. The walls of both arteries were firmly adherent. The canal was almost completely occluded by the invaginated portion. Line of union was a little difficult to locate with the naked eye. The calibre of the vessel

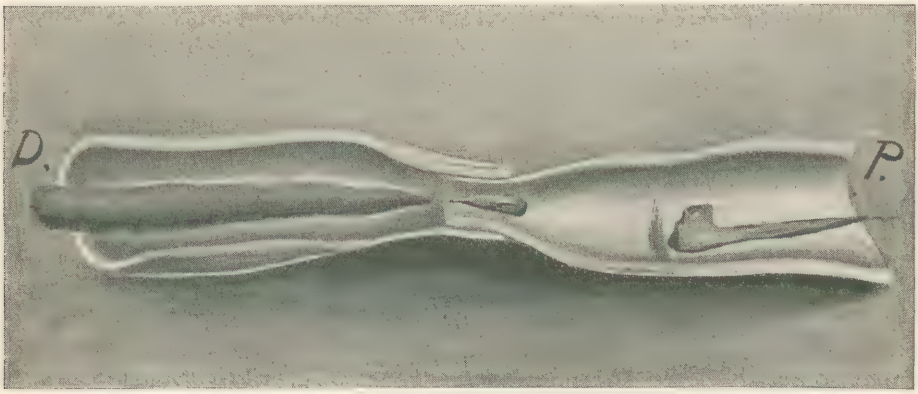

Fig. 8.—Shows Contraction of Artery at Line of Suture, with Clots on Proximal and Distal Sides, from Experiment No. 19.

was so small that the clot at the point of union was about one sixty-fourth of an inch in diameter.

Experiment No. 20.—Same sheep as in Experiment 19. Right common carotid artery. Transverse incision; end-to-end invagination. Artery invaginated with four needles threaded with silk. Adventitia was carefully peeled off. At one point hemorrhage took place, but was checked by an additional suture. Sutures were dipped in beeswax before insertion.

Post-mortem: The artery on the right side was thrombosed for three-eighths of an inch on proximal side and three inches on distal side of the line of suture. The clot was not adherent to the wall of the vessel above or below the line of approximation, showing that it originated at the line of union. There was no hemorrhage between the adventitia and the media where the former overlapped the line of union, showing it was completely sealed. The artery was very much diminished in size where the four invaginated sutures were tied. There was a discoloration and apparently a rupture of the intima at the position where the temporary hæmostatic ligature was placed. A small clot existed on the proximal side of the suture; both layers of both walls were firmly adherent, requiring considerable force to separate them. The agglutination of the walls was very firm. The cali-

bre of the artery was diminished to the size of a knitting needle at the position of invagination (Fig. 9). The clot formed from the end of the intussusceptum. One of the stitches crossed on the inside of the artery, to which the clot was firmly adherent. There was a slight roughening of the intima where the temporary ligature had been attached, and a small clot one-half of an inch in length formed at that position.

Experiment No. 21.—October 29, 1896; sheep, weight about eighty pounds. Excision of one-third inch of left common carotid. End-to-end continuous suture of wall of artery which was not invaginated; sutures waxed while wet. Considerable hemorrhage; three additional stitches were inserted. Hemorrhage controlled by forceps while operating. Adventitia sutured over line of union; sheath replaced and sutured. Irregular active rhythmic contraction of coats of wall of artery noted after removing adventitia.

Post-mortem: November 3, 1896, left common carotid. Clot on distal side occluding artery. Artery contracted and bent at a right angle. There had been hemorrhage around the line of union; no suppuration. Line of

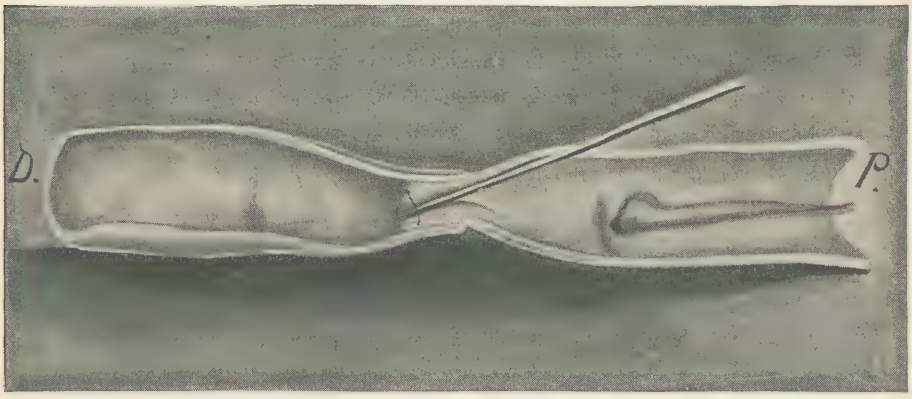

Fig. 9.—Shows the Marked Diminution in the Size of the Lumen of the Vessel at the Point of Approximation, from Experiment No. 20.

union was difficult to make out. Specimen retained without opening the lumen of vessel.

Experiment No. 22.—Same sheep on same day as Experiment 21. Oblique incision in right common carotid artery, one-third inch long, was made: continuous silk suture including all coats. When the adventitia was removed there was a rhythmical contraction of the artery, the same as in an intestine when injured. Artery diminished one-third in diameter (see Fig. 10). No hemorrhage followed the removal of forceps.

Post-mortem: November 3, 1896, right common carotid. Clot extended one inch to the proximal side and one-half inch to the distal side of the line of suture. This was very small; it had formed over the position of suture, but was not adherent to the wall of the vessel. It did not completely fill the vessel and extended upward from the line of union to the line of fracture in the intima, where it was again adherent. Over one-half of the line of union the silk was covered so that it could not be seen. The artery had been fractured by the clamp.

Experiment No. 23.—Sheep. Operated October 31, 1896. Resection of one-half inch of left common carotid; artery invaginated with four double-needled sutures. The adventitia of the proximal side was torn back; then

the proximal was drawn into the distal, bringing the media of the proximal in contact with the intima of the distal. The edge of the intussuscipiens was then approximated with two sutures to the periphery of the intussusceptum. The adventitia of the intussusceptum was then drawn over the line of union and sutured to the periphery of the intussuscipiens, making the order of the coats overlapping each other from within outward: two internal coats of proximal, three coats of distal, adventitia of proximal.

The sheep used for this and the following experiment died November 14th. Post-mortem of left common carotid. Thrombosis at the position of union and a fracture of artery on the proximal side where the hæmostatic forceps had been placed, but no clot adherent to it. On the distal side there was also a fracture of the artery with a clot adherent. A thrombus which did not completely fill the artery existed from this point to the line of suture. The two coats were firmly adherent and could not be separated without laceration. There was a firm connective-tissue deposit outside completely covering the line of union, so that it could not be recognized. There was no hemorrhage around the seat of union. The greatly dimin-

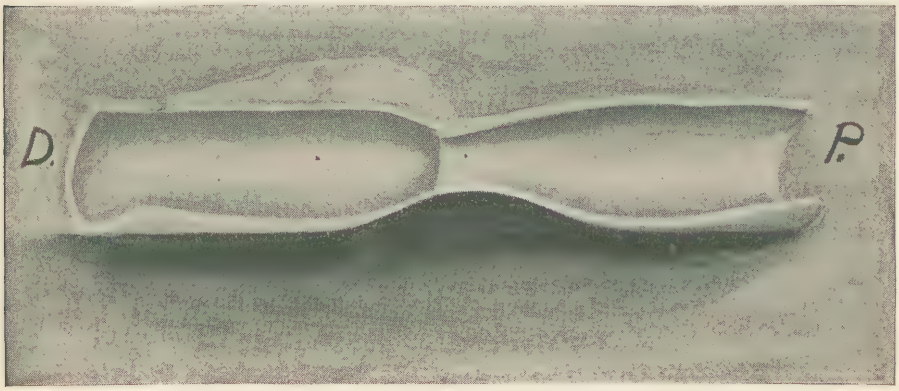

Fig. 10.—Shows the Usual Contraction at Seat of Approximation. See Experiment No. 22.

ished size of the artery at the position of invagination was, I believe, the cause of the formation of the clot. Only one suture was exposed outside the exudate and that was the one used to draw the adventitia over the line of approximation. Specimen given to pathologist for sections.

Experiment No. 24.—October 31, 1896; same sheep as in Experiment 23. Right common carotid artery. A V-shaped incision of one-fourth of an inch on each side was made. It was closed with a continuous suture of six stitches involving all coats of the artery. The sheep was very sick for two days before death, showing all symptoms of sepsis.

Post-mortem, November 14th, fourteen days after operation: All of the tissues of the neck were infected. There was an absence of union in a portion of the skin and a most offensive discharge of pus and blood. The tissues of the neck were so much inflamed that their recognition was difficult. A clot the size of a walnut existed on the anterior side of the artery at the line of suture. A thrombus filled the proximal side for a half-inch from the opening in the vessel. The opening had increased to three-fourths of an inch in length on the anterior surface of the vessel, showing that there had been an elongation of the opening by a necrosis of the wall of the vessel at the line of suture. The clot had a very offensive odor; pus surrounded

the wall of the artery. The distal end of the artery was closed by a thrombus up to the head. This specimen shows the destructive effect of infection in arterial suture better than any of the former ones. Cause of death, sepsis.

Experiment No. 25.—November 2, 1896; sheep, weight about seventy pounds. Resection of one-fourth inch of right carotid artery; invaginated; continuous external suture. Artery very small; adventitia not removed; silk had been boiled in a saturated solution of oxalate of ammonium and waxed. Sheath closed over artery with a few catgut sutures.

Post-mortem, November 30, 1896: There was no clot on proximal side of suture, no infection at point of suture. A white organized thrombus existed, filling the vessel. The exact line of union could not be seen when the thrombus was removed. Thrombus extended for one-half inch on the distal side of the line of suture. Specimen was given to Dr. Evans for examination. Union of ends of artery from a macroscopic standpoint was perfect.

Experiment No. 26.—November 2, 1896; same sheep as in Experiment 25. Transverse incision of one-half the circumference of the right jugular vein. Opening closed with a continuous silk suture, which was oxalated and waxed. The wall of the vein was very thin and required considerable care to prevent its laceration with the suture. It was diminished considerably in size by the suture.

Post-mortem, November 30, 1896: Periphlebitis existed at the site of suture. There was no thrombus in the vein. The diameter of the vein at the point of suture was about one-third of its diameter above and below. A white exudate covered the line of suture.

Experiment No. 27.—November 2, 1896; same sheep as in Experiment 25. Complete division of left jugular vein; edge-to-edge union with continuous oxalated waxed silk suture. Wall of vein was very thin. The continuous suture contracted the vessel to about one-half its normal size. There was but little bleeding after the digital pressure which had been used for hæmostasis was removed.

Post-mortem, November 30, 1896: Periphlebitis of slight degree existed; no œdema or evidence of infection. When the vein was opened, it was found that there was a complete occlusion by adhesion at the line of suture. There was not the slightest thrombus on either the distal or proximal side of the suture. The thickening from the exudate at the line of suture was scarcely perceptible. The vessel appeared to have retained its normal diameter on the proximal and distal sides of the suture.

Experiment No. 28.—November 3, 1896; sheep. Resection of one-third inch of left common carotid. End-to-end approximation of artery with continuous oxalated waxed silk suture. There was considerable hemorrhage from artery when clamps were removed, which ceased with slight pressure. Adventitia was not removed.

Post-mortem, November 30, 1896: The diameter of the artery above and below the point of approximation was one-eighth of an inch. The artery was thrombosed for one inch on distal side and three-fourths of an inch on proximal side of suture. The sutures were infected; the lumen of the artery was entirely obliterated.

Experiment No. 29.—November 3, 1896; same sheep as in Experiment 28. A semilunar piece one-half inch long, involving one-half the circumference of the left jugular vein, was excised. The opening was closed with a continuous oxalated waxed silk suture; but very little bleeding after pressure hæmostatics were removed.

Post-mortem, November 30, 1896: A thickened inflammatory cord existed at the site of the suture. There was some œdema of the surrounding

tissue; about one-fourth of the lumen of the vein was patulous. A white exudate covered the sutures within the lumen of the vessel. There was no thrombus.

Experiment No. 30.—November 8, 1896; black dog, weight about forty pounds. A transverse division through all coats of one-third of the circumference of the abdominal aorta, one inch above its bifurcation, was made. A continuous silk suture of seven stitches was inserted, including all of the coats of the artery. The silk had been boiled in a saturated solution of oxalate of ammonium. The adventitia was peeled off the artery. The suturing was done with a full curved sharp needle with cutting edges. The needle was inserted so closely that three of the openings cut into one; some bleeding took place from this point when the clamps were removed. Two additional stitches were required. The abdomen was closed with two rows of continuous catgut sutures.

The dog was killed December 5, 1896, twenty-seven days after operation. The abdominal wound was entirely closed. The dog had increased much in weight. There was no peritonitis; a slight elevation of connective tissue on the anterior surface of the artery at the site of suture was noted. The artery was divided; it was very slightly contracted in size at the line of suture. The silk was covered over by a thin white fibrinous exudate. There was a slight depression of the surface at the site of union. The arterial wall was perfectly healthy above and below, showing none of the effects of the compression clamps. From a macroscopic point of view the greatest support given the artery was from the connective tissue on the outer wall. Specimen was given to pathologist for examination. This specimen illustrates beautifully the process of repair when the field is kept aseptic.

Experiment No. 31.—November 8, 1896; black hunting-dog, weight thirty-five pounds. Left common carotid; a longitudinal incision two centimetres long was made. It was closed with a waxed silk suture which had been boiled in a saturated solution of oxalate of ammonium, and included all the coats of the artery. The technique of the operation was the same as in the other experiments. Seven stitches were inserted in the artery; there was no hemorrhage after hæmostatics were removed.

Post-mortem, November 24th: A small clot was found, one-third the size of the calibre of the artery, not adherent to it except at point of infection. A pocket of pus, one-fourth of an inch in diameter, existed around the point of suture, showing that the stitches had been infected. On the proximal side of the suture the clot filled the vessel for one-fourth of an inch and was adherent. A small free clot existed for three-fourths of an inch on the distal side.

Experiment No. 32.—November 8, 1896; same dog as in Experiment 31. Both carotids were exposed by an incision deep in the neck. A longitudinal incision, one and one-half centimetres long, was made in the right common carotid. It was closed with a continuous waxed oxalated silk suture, including all of the coats of the artery. There was no hemorrhage when the hæmostatics were removed. The incision was closed with a continuous suture of catgut.

Post-mortem, November 24th: The dog died on the evening of November 23d. A sinus leading from the external opening was traced down to the opening in the vessel. The clot around the vessel had suppurated, and the sutures had cut through the vessel. There was no thrombus within the lumen. A small white clot was adherent close to the margin of the wound; there was no effort at definitive union. Cause of death, hemorrhage.

Experiment No. 33.—November 10, 1896; calf, eight months old. A

resection of one-third inch of right common carotid was made. Invagination by three internal sutures and seven external sutures. The artery was the size of the common femoral in man; no blood escaped; sheath around artery was sutured with catgut; no drain. The invaginating sutures in this case were inserted differently from those in any of the preceding experiments. They included only the adventitia and media of the invaginated portion, and when tied were not exposed in the lumen of the artery in any place (Fig. 11). By this method the size of the artery was not diminished in the same degree as it had been in any previous experiment. It can be seen that by this method there was no foreign body left in the lumen of the artery, as had been done in the previous method of invagination, and therefore there was less likelihood of thrombosis. The peripheral sutures included only the media and adventitia. Temporary hæmostasis was produced by a fine strand of gauze tied firmly around the artery. Specimen removed December 5th. Primary union of the external wound had taken place; an extensive induration two and one-half inches in length by one and one-half inches in diameter was found at the site of approximation. This mass was carefully dissected out and the artery was found patulous at each end, although considerably diminished in size. On opening the mass it was found to be a pus pocket, about three-fourths of an inch in diameter. In the centre were found the necrotic ends of the artery and the sutures. The infection had occurred at the suture. The vessel was thrombosed for one-third of an inch on either side of the abscess. The ends of the artery in which the sutures were inserted were well preserved, though the vessel had been amputated by the inflammatory action on either side of the abscess. The thrombi were very firmly adherent to the intima.

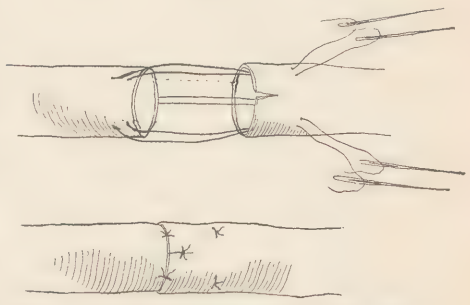

Fig. 11.—Shows Method of Insertion of Sutures in Experiment No. 33.

Experiment No. 34.—November 14, 1896; large black calf, about eight months old. A transverse division of right common carotid was made; end-to-end union by invagination; kangaroo tendon furnished by Dr. Longyear, of Detroit, was used. Three invaginating and six external sutures were inserted, as in Experiment 32. No escape of blood after removal of clamps. Adventitia was peeled off and returned over the line of suture. Fascia and sheath were sutured over the artery. A strand of gauze was tied around the artery to produce temporary hæmostasis. The vessel was a little larger than the common femoral in man. Pulsation was normal on the distal side of the approximation immediately after operation.

Specimen removed December 5th. There was no induration or inflammatory action around the site of approximation. Some connective-tissue formation outside the adventitia was found. There was but one suture exposed within the lumen of the vessel, and that for only a very small extent. When the vessel was opened, a thrombus existed on the proximal side of the line of union for one-half an inch, completely occluding the vessel. This was firmly adherent for the first half of that space; over the line of union and for one-fourth inch on the distal side the thrombus was not adherent; again it was adherent for one-fourth inch, occluding the vessel.

It should be noted that the points of adhesion and formation of the thrombus were where the temporary ligatures were placed during the operation, showing that the injury done the artery by the ligature was the cause of the thrombus. The union between the two walls of the artery was firm. The kangaroo tendon appeared to be as hard and as firm as when it was inserted.

For convenience in treating the subject of arterial and venous suture, we will consider: (1) The pathologic histology of repair of blood-vessels. (2) The class of arteries and veins amenable to suture. (3) The degree of destruction that may exist and still leave the vessels within the range of repair by suture. (4) The technique of vessel suture. (5) The prognosis of arterial and venous suture.

Pathologic Histology of Repair of Arteries and Veins.—That the clinical aspect of the subject may be better appreciated, let us first consider the histology and physiology of the vessels and blood.

Structure and Properties of Arteries and Veins.—The arteries and veins of the body are the channels through which the blood is carried to and from the tissues and organs. The thin-walled capillaries bring the blood into intimate relation with the cells by transudation and migration.

The arteries are distinguished from the veins by their thicker walls due to the greater development of smooth muscular and elastic tissue. The middle coat of the artery is especially thick, while the outer coat is relatively thin.

The arteries consist of three coats, and are derivatives of the mesoblast. The tunica intima, or inner coat, consists of a layer of irregular or oblong fusiform nucleated squamous cells forming the excessively thin transparent endothelial coat immediately in contact with the blood stream. These cells have oval nuclei and the long axis of the nucleus and cell is parallel with the long axis of the artery. The endothelial cells have no distinct blood supply, still they have the power of reproduction, and are possessed of marked potential reactive properties when disturbed mechanically or chemically. This was appreciated first by Jones, who showed in his experiments that on account of its regenerative properties it was necessary to injure the intima to produce successful ligation of the arteries. These endothelial cells are held together by a cement substance. Outside of these lies a very thin, more or less fibrous layer, sub-epithelial, in which numerous spindle or branch-shaped protoplasmic cells lie embedded, with a corresponding system of plasma canals. Outside of this is an elastic lamina. In arteries of medium size it is a fenestrated membrane, while in the largest arteries there may be several elastic laminæ, or fenestrated membranes, mixed with connective tissue. In middle-sized arteries and in larger arteries a few non-striped muscular fibres are disposed longitudinally between the elastic plates or laminæ along with the circular muscular fibres of the middle coat. They may act so as to narrow the artery, but they may also aid in keeping the lumen of the vessel open and of uniform calibre. It is not probable that when they act by themselves they dilate the vessels. The nourishment of the intima is entirely independent of the media and adventitia. Its nutriment is received directly from the blood within the artery.

The tunica media, middle coat, or muscularis, contains much non-striped muscle, which in the smaller arteries consists of transversely disposed non-striped muscular fibres lying between the endothelium and the adventitia, while a finely granular tissue with a few elastic fibres forms the bond of union between them. As we proceed from the very small to the larger arteries, the number of muscular fibres becomes so great as to form a well-marked fibrous ring of non-striped muscle in which there is comparatively little connective tissue.

In the large arteries the amount of connective tissue is considerably increased, and between the layers of connective tissue numerous thick fibres or fenestrated laminæ are concentrically arranged. From a clinical standpoint it can be seen that this coat is composed of histological elements which have very little, if any, power of regeneration. Repair of injury to these elements is accomplished by the formation of new connective tissue. Ballance and Edmunds claim that the vasa vasorum penetrates this coat. It is certain from the experiments of Bruci (Pisa, 1893) that the media receives its nutriment from the adventitia either by vessels or nutrient canals, as he demonstrated that a necrosis of the media took place when the adventitia was removed and prevented from readhering by wrapping gutta percha around the vessel; but the intima was not affected by this procedure, except to show evidence of increased proliferation. When the adventitia is torn off and immediately replaced, the alteration of the muscularis is scarcely discernible.

The tunica adventitia or outer coat in the smallest arteries consists of a structureless membrane with a few connective-tissue corpuscles attached to it. In the somewhat larger arteries there is a layer of fine fibrous elastic tissue mixed with bundles of fibrillated connective tissue. In the arteries of medium size and in the largest arteries the chief mass consists of bundles of fibrillar connective tissue containing connective-tissue corpuscles. The bundles cross each other in various directions and fat cells often lie between them next the media; this accounts for the loose adhesion of the two coats and also for the ease with which the adventitia may be peeled off from the media. There are numerous fenestrated and fibrous elastic laminæ. In the medium-sized and small arteries the elastic tissue next the media takes the form of an independent elastic membrane. It contains blood-vessels to the wall, the vasa vasorum, which are supplied from the nearest branch and not from the main trunk of the artery; these vessels usually extend to the media, never to the endothelial cells. It also contains nerves, the small axis cylinders extending through all the coats to the endothelial cells and intercellular substance.

The veins have the same anatomical construction, except that the wall is thinner on account of the smaller amount of non-striped muscle and elastic tissue; there is no noticeable primary contraction of the veins when injured, as there is in the arteries. They are more extensile under the same strain. The adventitia is usually the thickest coat.

The large blood-vessels are therefore cylindrical tubes composed of several layers of tissue, more especially elastic tissue and plain muscular fibres. One of the important properties is contractility of the vascular wall, by virtue of which the blood-vessels may be elongated or shortened, the diameter of the vessel may be dilated or contracted and the supply of blood to a part altered; this contractility plays no small part in the surgery of the vessels. Their elasticity is great, that is, they offer little resistance within certain limits to any force employed to distend or elongate them; if the force be uniform the blood-vessels rapidly regain their original size and form, after the force distending them is removed.

The extent to which the arteries may be stretched has not been accurately estimated. Veins may be stretched fifty per cent. without passing the limit of their elasticity; *i.e.*, when a vein is freed from its adhesions to surrounding tissue, fifty per cent. of the distance may be removed and still the vein possess sufficient elasticity to be approximated. From personal observation I have found that a large portion of carotid arteries could be removed and the ends approximated without difficulty. The internal pressure which a vessel will withstand is very much greater than the normal arterial pres-

sure to which it is subjected, showing that, in the process of surgical repair, a wall much more feeble than the normal wall of the vessel is sufficient to hold the blood in control. Volkmann found the carotid of a sheep would rupture only when fourteen times the normal pressure was put upon it. The carotid of a dog withstood fifty times the normal blood pressure; the jugular vein about one-half of this (Greheut and Quinquand). It may be deduced from the above that there is little danger of aneurism at the point of union, even if the walls are somewhat weaker than normal.

Thrombosis and Coagulation.—Blood in direct contact with living unaltered blood-vessels does not coagulate (Hewson, Brücke). Coagulation takes place within an injured blood-vessel after death of the leucocytes. The action of the paraglobulin on the fibrinogen in solution in the plasma produces coagulation, if salts of calcium be present. Paraglobulin is believed to be the product of disintegration of cellular elements of blood, principally leucocytes and blood plates. Peptones injected into the blood of a dog do not permit of the interaction of lecithin, and thereby prevent coagulation (Wooldridge). Freund believes that the death of the red blood corpuscle causes conditions which produce coagulation. He showed that blood collected in glass vessels smeared with vaseline did not coagulate for a long time if decomposition was prevented. Experiments further show that apparently unimportant changes in the condition of the vessel wall may cause coagulation; this result is confirmed by the observations of many pathologists. "All observers are agreed," writes Thoma, "that the solution of the red blood corpuscle causes coagulation, although they differ as to the explanation." It is probable that the splitting of the fibrinogen molecule is produced by the nucleo-proteid and the thrombosin thus formed combines with the calcium; fibrin is a salt of calcium. Albertoni observed that if tryptic pancreas ferment or histon be injected into the blood of an animal, the blood would not coagulate. The three factors necessary for coagulation are fibrinogen, nucleo-proteid in considerable quantity, and calcium salts. The coagulation is favored by contact with foreign substances of all kinds, but only when it adheres to them. Blood does not readily coagulate in contact with bodies covered with fat or vaseline. Waxed sutures prepared in oxalate of ammonium should, therefore, be used when the intima of an artery is penetrated. We have been taught that a roughening or irregularity in the wall of an artery would produce coagulation thrombosis. My observations on arteries lead me to believe that this statement is erroneous and that thrombosis occurs only when a foreign body is left in the artery to which the blood adheres, or when an infection is present with the foreign body, causing the death of cellular elements of the blood. The theory that injuries to the intima, *per se*, do not produce thrombosis is supported by Porta's observations that thrombosis of the artery was absent in fourteen per cent. of the ligations made by him where the intima was injured, and Schumann found experimentally that thrombosis occurred in a very much smaller percentage of cases. Senn observed that a clot was not formed on the proximal side of ligatures in veins, but always on the distal side. These show that trauma of the ligature, in itself, does not produce coagulation in the vessel.

As a proof that an irregularity in the wall of an artery does not produce thrombosis, we have the clinical fact that arteries penetrated by bullets rarely ever thrombose. They almost always form dissecting aneurisms, and there is no tendency to coagulation within the vessel at the seat of the injury, nor below that point if sufficient of the wall remains to guide the current of blood into the distal portion. In Case II. of this paper, notwithstanding that the artery had been completely penetrated by the bullet,

leaving the irregular edges of the arterial coat projecting into the lumen of the vessel, there was not the slightest tendency to the formation of a clot within the vessel nor on the ragged edges of the wall. This observation is supported by the clinical course of traumatic aneurisms, and numerous cases may be cited to support this theory, that the roughened edges do not produce coagulation. There is no doubt that even a considerable destruction of the intima does not always cause thrombosis, and that this process is lessened if the calibre of the vessel is reduced to certain limits in accordance with Thoma's histo-mechanical principle. Virchow, O. Weber, Paget, and Billroth believed that after ligation of the artery its permanent obliteration is produced by thrombosis and vascularization of the thrombus, and that tissue proliferation within it proceeds from the white blood corpuscles. Rokitansky showed that primary adhesion and definitive occlusion can take place independent of thrombosis. Senn verified this by his experiments. Kocher in 1869 proved that a ligature with primary adhesion of the endothelium would produce closure of an artery. This was further sustained by Lister, Baumgarten, Raube, and others. Waldeyer sustained the belief that the endothelium and subendothelial layer take an active part in producing adhesion of the wall of the vessel after ligation, that the intima receives its blood supply from the capillaries of the media, and that organization takes place from the endothelial lining which forms the basis of a new connective tissue.

Scarpa, recognizing that the endothelial coat of the intima is a derivative of the mesoblast, as the other serous surfaces, the peritoneum, pleura, pericardium, dura, etc., attributed to it the same physiological properties of regeneration. Its reaction to irritants is very much less than that of the peritoneum and much more than that of the dura, being about midway between the two.

The union between the walls of arteries after ligation takes place more rapidly without the formation of thrombus, that is, a thrombus is a foreign body and retards organic union in arterial approximation, whether with ligature with intent of definitive occlusion, or with suture with the purpose of definitive union of the walls. The former was well recognized by Baumgarten. The endothelial cells increase in number, producing long spindle cells and broad embryonal connective-tissue cells from beneath them (Raab). If vessel walls the same as peritoneal surfaces be brought in close approximation after irritation, they adhere primarily through cell proliferation from the intima by the process of budding of endothelial cells and division of connective-tissue cells. The remaining coats of the vessels assist in the definitive organization and vascularization of these adhesions, that is, the media is penetrated by vessels from the adventitia, and capillary loops are formed and joined until organic union is complete.

The subsequent changes in the thrombus are divided into five classes: (1) Hyaline-granular transformation. (2) Organization or replacement by connective tissue and re-establishment of the calibre of the vessel. (3) Calcification. (4) Simple softening. (5) Puriform liquefaction. After an artery has been thrombosed, the thrombus may entirely disappear and continuity of the canal be established. Its absorption is produced by the endothelia of the vessel covering the thrombus and the formation of connective-tissue cells. This gradually produces contraction of the thrombus, as shown in Figs. 195, 196, and 197, page 206, Thoma. Vessels from the vasa propria finally penetrate the intima and media of the vessel; absorption takes place, leaving the vessel patulous and its wall free (Thoma-Heuking).

Ischæmia, Collateral Circulation.—If the trunk of a large vessel be sutured and thrombosis takes place at the seat of union with complete

occlusion of the vessel, the life of the part on the distal side will be jeopardized by the interruption in the circulation in proportion to the rapidity with which the circulation is shut off and the rapidity of the establishment of the collateral circulation, which plays an important part in retaining vitality and which requires time for its development. Permanent occlusion of an artery leads, as a general rule, to a permanent alteration and re-arrangement of the vascular system and generally to the development of collateral circulation (Thoma). After ligation of the main artery of an extremity, there is at first a disappearance of pulsation in all the branches. This will remain absent until such time as the circulation is re-established directly through the vessel or by enlargement and development of collateral branches. This can take place with great rapidity after ligation of a large trunk, as of the popliteal and femoral; the return of pulsation in the large vessels below can occur as early as twenty-four hours in the young, and proportionately later in older persons. The veins play an important rôle in the re-establishment of this collateral circulation, so that when the vein and artery are both occluded the danger of death to the extremity is much greater than when only one of them is occluded. Upon ligation of large arteries, corresponding to the first and second divisions, the vessel on the proximal and distal sides of the ligature contracts within five to ten minutes after it is tied, and remains permanently contracted, showing that the diameter of the artery is independent of the blood pressure (Thoma). When a blood-vessel is diminished in size, the tension on the wall at that point decreases. On the basis of this histo-mechanical principle, the invaginating method of the union of arteries diminishes the calibre of the vessel at the position of union, and therefore the tension diminishes while the blood current at that point increases in rapidity. The resisting power of the wall at the point of invagination is above normal, as the arterial coats are doubled at that point. From a mechanical standpoint the danger of rupture, dilatation, or thrombosis is lessened when the approximation has been made, as the diameter of the vessel at that point is smaller and the current more rapid. Experience shows that the gradual occlusion of a vessel always leads to the development of an increased collateral circulation; even the thoracic aorta comes under this rule. After suture of vessels there is a tendency to endarteritis obliterans. As this process is one of slow formation, it is one of minor importance as to the ultimate result of arterial suture. While the endarteritis is occluding the vessel, collateral circulation is being established and the danger of death of the part obviated.

The Effect of Ligature of Large Vessels.—The abdominal aorta has been ligated 10 times; one patient survived 10 days after the operation. The common iliac has been ligated 68 times (Lidell) with only 16 recoveries, a mortality of 76.5 per cent. In 31 cases of ligation of the femoral artery for aneurisms, hemorrhage occurred in 18, *i.e.*, 60 per cent., and was fatal in 12, or 40 per cent. (Ballance and Edmunds), a mortality somewhat less than that of ligation of the common iliac, which is 67 per cent. Kammerer collected 28 cases of ligation of the femoral vein, with gangrene in 2; in 22 cases of ligation of femoral vein and artery, gangrene followed in 12; in 178 cases of ligation of the artery alone, gangrene occurred in 25.[1] Billroth in 1871 and 1872 found that he had secondary hemorrhage from 50 per cent. of large vessels ligated in continuity. Of 106 cases of aneurism of the common carotid, collected by Wyeth, with ligation on the proximal side of the aneurism, 67 terminated in recovery, a mortality of 35 per cent. In ligation for aneurism of the external carotid, according to statistics col-

[1] New York Medical Journal, May 10, 1891.

lected by the same author, there were 17 recoveries and 5 deaths, a mortality of 22 per cent. For aneurisms of the common carotid alone the death rate was 44 per cent. Lipp collected 130 ligations of the external carotid; only two died as a result of the ligation and these from extension thrombosis. In ligations of the internal carotid 13 to 18 per cent. succumbed to brain lesions (Fenger, Lyons, 1894). Ligation of the trunk of the portal vein terminates in death (Lépine).

The necessity of suturing arteries and veins depends upon their individual importance to the tissue on the distal side of the injured part; that is, we are called upon to suture arteries and veins only in cases in which by their obliteration there would probably be a necrosis or impairment of the vitality of the tissue supplied by them to such an extent that its normal functions would not be performed. Therefore in the upper extremities we shall not be concerned with the arteries below the brachial; in the neck not above the common carotid; in the abdomen we are concerned with injuries to the aorta, renal, splenic, hepatic, and iliac vessels. Suture of the portal vein is particularly desirable, as in President Carnot's case. The greatest need for arterial suture exists after injury to the so-called terminal arteries, but they are the least accessible.

The Extent of the Arterial Resection.—I found that more than one inch of a calf's carotid could be removed and the ends could still be successfully invaginated with sutures. The vessels are very elastic, and when separated from surrounding tissues can be stretched to quite an extent. In dogs three-fourths of an inch could be readily removed and the vessel approximated and sutured. I believe the endarteritis in some of my experiments was caused by the stretching of the vessels and by denuding them of their connective tissue to such a large extent in order to elevate them. In many cases three inches of a vessel was freed from all connection before the hæmostatic forceps were applied. From my observations I cannot believe that a vessel can be repaired with safety when more than three-fourths of an inch is removed, except possibly in the popliteal space, Scarpa's triangle, or in the axillary space, where the position of the limb can be made to relieve the tension of the vessel.

The Technique of Arterial Suture.—For convenience I will divide these experiments on the arteries into four classes: (1) Longitudinal incision; (2) transverse or irregular wounds involving not more than one-third of the circumference of the artery; (3) transverse sutures involving more than one-half of the circumference of the artery; (4) complete division and resection of the artery not exceeding three-fourths of an inch.

The points to be considered in the technique are: (1) Complete asepsis; (2) exposure of the vessel with as little injury as possible; (3) temporary suppression of the blood current; (4) control of the vessel while applying the suture; (5) accurate approximation of the walls; (6) perfect hæmostasis by pressure after the clamps are taken off; and (7) toilet of the wound.

The arterial wall and its endothelium are products of the mesoblast the same as the peritoneum, and react excessively to irritation, but much more slowly than the peritoneum. Infection must be assiduously avoided, as we have not only the regenerative action of the vessel walls interrupted but also the action of the cellular elements of the blood forming a thrombus in their efforts to prevent the admission and advancement of sepsis in the vessel. If we have a suppuration outside the wall of the vessel, we may have a penetration of the infection to the inner wall and a thrombosis, failure of union from infection, or necrosis of the vessel when it is exposed to the action of the pus germs, as shown in Case I.

The vessel wall should be thoroughly exposed and the field prepared. The loose connective tissue should be freed with scissors and dissecting forceps for the required distance above and below the site of operation. If the operation be for a dissecting aneurism, it is well to expose the vessel above and below the tumor so as to control the hemorrhage; then open the aneurismal sac, remove the clot, expose the injured wall of the vessel, freshen the edges of the wound, and suture.

Control of Hemorrhage during Operation.—I find this is best accomplished by a delicate eight-inch Billroth forceps with a broad blade and graduated catch. The blades are first covered with a rubber drainage tube to prevent them from injuring the vessel; the forceps are closed just sufficiently to control the hemorrhage and hold the vessel in the correct position for approximation. If these forceps are not at hand a heavy twisted silk ligature may be used for the purpose; it must not be tied so firmly as to fracture the intima, and is best secured with a loop knot, so as to be readily removed when the operation is completed.

The Control of the Vessel while Applying the Suture.—The best instrument to use is the small rat-tooth catch forceps used by oculists, known as the fixation forceps. The intima should never be clasped with the forceps. The ordinary hæmostatic forceps should not be used in any place on the vessel, as it fractures the coats. The adventitia is sufficiently strong to control the vessel during the operation and is all that is necessary to be included in the fixation forceps.

Accurate approximation of the edges of the wound may be accomplished with needles and suture material. The former should be the same as are used by ophthalmologists and known as the full-curved sharp and round conjunctiva needles. The straight "floss needles," sizes 6 to 10, are very serviceable in experiments on the limbs or neck when the artery can be thoroughly exposed. The ordinary cambric needle may, however, be used, or, better, a fine cambric needle with an elongated eye. The suture material which I found most serviceable in my experiments was twisted silk. The needle and silk should correspond in size, so that the opening made by the former may be filled by the latter. Effort should be made in suturing lateral openings to have the sutures enter only the tunica adventitia and media, the tunica intima being avoided, as advised by Jassinowsky. The sutures should be inserted every one-sixteenth or one-twentieth of an inch; they should be interrupted, should enter the vessel one-sixteenth of an inch from the margin of the wound, and should not include the tunica intima. The reason for not penetrating the intima is not the danger of hemorrhage but of the endarteritis and obliterating thrombosis that might follow.

The ordinary double knot should be used, not too firmly tied. When the wound is transverse or irregular, care should be exercised in inserting the needle in parts that belong directly in apposition to each other. If one-half or a greater division of the artery be incised, the first suture should be inserted in the middle of the incision, then one at each angle.

After the sutures are all inserted the compression forceps should be removed from the distal side first. If there should be hemorrhage from the needle punctures, a compression with the fingers or sponge for from one to three minutes will be sufficient to control it, as a small thrombus forms in each puncture. When it is possible after the approximation is completed, it is advisable to suture the sheath of the vessel, muscle, or fascia over the line of union, to give it additional support.

The field of operation should be thoroughly cleansed after the operation is complete and a gauze drain inserted. In bullet wounds the bullet should be

located and removed, as it might be a source of infection. An accurate approximation should then be made of all tissues with buried catgut suture. The drain should be removed in forty-eight hours.

Jassinowsky's experiments were confined to incised and irregular wounds involving not more than one-half the circumference of the vessel. I found that when more than half the vessel was destroyed, it was not advisable to suture the edges end-to-end, but to make a resection of the injured portion of the vessel and produce an end-to-end union by invagination. The sutures are inserted as shown in Fig. 11; two or three double-needled threads are prepared and inserted into the end of the proximal portion, including only the two outer coats; these are reinserted at regular intervals one-third to one-half inch above the end into the distal part from within outward; the threads are then tied and this invaginates the artery. In order to facilitate the invagination a small incision is made parallel to its long axis, extending from one-fourth to one-third of an inch; then four or five interrupted sutures are inserted into the intussuscipiens, binding it to the surface of the intussusceptum, the suture in the latter entering only the tunica adventitia and media. By this method we have secured a large surface contact of vessel, the proximal portion of the vessel being inserted into the distal. The arterial blood pressure tends to press the walls closer, thus preventing hemorrhage and favoring definitive union. By this method of approximation fewer sutures are necessary to secure blood-proof apposition.

In experiments it is important to use large-sized vessels, as the lumen of small ones is apt to be filled by a thrombus. The work is delicate; the vessels must be handled with all possible care, as every injury to the intima means inflammatory reaction for repair.

The veins may be subjected to the same treatment with better results.

The indications for operation are:

1. Injuries to large vessels in operation.

2. Injuries to large vessels from stab, puncture, bullet, or lacerating wounds.

3. Traumatic and dissecting aneurisms.

4. Sacculated, fusiform, and arterio-venous aneurisms (see Figs. 19 and 12, 13, 14 and 16).

In the first class of cases, *i.e.*, injuries to large vessels in operation, the injury to an artery, if less than two-thirds the circumference be involved, should be immediately repaired by suture. If more than two-thirds the circumference be injured, the division should be made complete and the invagination method used for approximation, care being taken that the invaginating sutures do not penetrate the tunica intima of the invaginated portion; that the external sutures do not injure the intima and are first inserted in the invaginated portion parallel to the long axis of the vessel and then inserted in the overlapping end (see Fig. 11). By this method the circumference of the artery is not diminished as it is when the suture is inserted transversely to the arterial axis. The sheath should be carefully sutured over the artery, as it gives additional support, and, if the general field of operation should suppurate, the line of union would thus be protected from infection. The field of operation should always be temporarily drained, as a blood clot prevents primary adhesions. When the edges of the arterial wound are ragged they should be freshened and clean cut before the suture is inserted.

In the second class of cases, *i.e.*, injuries to large vessels from stab, puncture, bullet, or lacerating wounds, the primary hemorrhage, as a rule, is not excessive, particularly when caused by bullet wounds, except when

the abdominal aorta or renal vessels are involved, as the tissues are irregularly torn and overlap each other in such a manner as to prevent the escape of blood and favor the formation of aneurism; therefore, we have ample time to make proper preparation for the suture of the vessel. The wound may have existed for weeks or months with the dissecting aneurism and still be amenable to suture, as the opening in the vessel itself enlarges but little with time, the aneurismal sac being formed from the surrounding tissues and laminated coagula (see Fig. 12). The technique of suture in this class of cases should be the same as in the first, after the aneurismal sac has been enucleated and the opening in the vessel has been exposed and separated from its attachment to the wall of the aneurism.

Fig. 12.—Shows Aneurismal Sac Formed from Connective Tissue and Laminated Coagula with No Enlargement of Original Opening in Vessel.

In the third class of cases, *i.e.*, traumatic aneurisms of long standing, we have the best variety of cases for arterial suture. The opening in the artery is usually small, the arterial wall is healthy, and a sufficient quantity of aneurismal stump may be retained to produce a firm line of approximation (see Fig. 12). From a theoretical standpoint, as well as from the result of experiments, there is no danger of the formation of aneurism at the point of primary suture for injuries and should not be for secondary suture, as in aneurisms of this class. The vessel should be exposed above and below the aneurism, and temporary hæmostasis obtained by a very mild compression forceps. The aneurismal sac should then be freely opened and dissected down to the position of the opening in the artery. The edges of the opening should be freshened and closed, the same technique being observed as in primary suture.

In the fourth class of cases, *i.e.*, sacculated, fusiform, and arterio-venous aneurisms, the aneurismal sac should be exposed and dissected down to the position of the healthy coats of the artery (Figs. 13 and 14), where it should be amputated, leaving sufficient of the aneurismal coat and arterial wall to allow a row of sutures involving one-sixteenth of an inch of the margin on either side, so that when the suture is complete the size of the vessel will be below its normal calibre. This lessens the arterial pressure of the vessel at that point and there should follow a union of the walls. Care should be taken not to produce an approximation of arterial surfaces covered with coagulated laminæ. A study of the aneurismal varix (Figs. 13 and 14)[1] shows how the aneurismal sac may be amputated or removed from the opening in the artery and the communicating canal closed by suture; also Warren's case.[2] The same can be said of Roland's case.[3] As the longitudinal suture of arteries has been so successful experimentally, little doubt remains but it can be more successful clinically, as asepsis and antisepsis can be more effectually carried out.

[1] Treves' "Surgery," p. 634.
[2] Boston Medical and Surgical Journal, May 30, 1890.
[3] Bryant's "Surgery," p. 316.

Following are reports of two cases in the human subject:

Case I.—Carl A. B——, American, aged thirty-three, married, a salesman; received a bullet wound in the left Scarpa's triangle (22-calibre ball) at two o'clock on the afternoon of October 4th. He was taken to the County Hospital, where I saw him at 6:45 the same evening. The man had profuse hemorrhage from the wound before he was brought to the hospital. There was considerable puffing for four inches below Poupart's ligament;

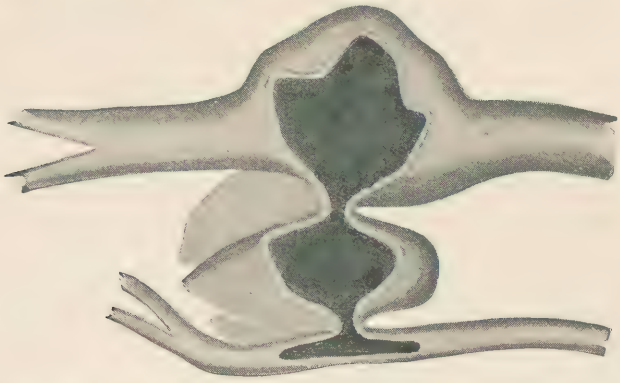

Fig. 13.—Shows Arterio-Venous Aneurism with Small Communicating Canal where Suture could be Readily Applied (Treves).

there was no pulsation or bruit in this swelling. The left posterior tibial artery pulsated synchronously with the right and was of the same force and tension. It was believed from these conditions, from the position of the wound, and from the severity of the hemorrhage, that the femoral artery was not injured but that the vein was probably punctured.

Operation: An incision five inches long was made, extending downward from Poupart's ligament parallel with the femoral artery; the internal sa-

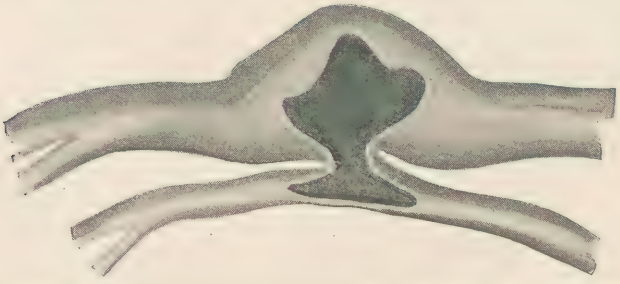

Fig. 14.—Shows Arterio-Venous Aneurism with Large Communicating Canal and No Dilatation of Artery at Point of Communication (Treves' "Surgery").

phenous vein was exposed and found to be perforated. An opening existed on its anterior and posterior surfaces, the bullet having passed through the middle. These were sutured with a continuous silk suture, No. 8 floss needle. The dissection was continued and the common femoral vein exposed and found injured. The femoral vein had an opening on its anterior surface, three-fourths of an inch above the junction of the profunda, and on its posterior surface one-eighth of an inch above the vena profunda femoralis (Fig. 15). It was difficult to control the hemorrhage, as the blood returned

through the vena profunda when the clamps were placed upon the femoral vein above and below the wound. It was soon found that the posterior opening could not be exposed without dividing the profunda. A double ligature was placed on the profunda and it was divided between. The posterior surface of the vein was now turned forward and the opening closed with a continuous suture as above. After this was completed the clamps were removed and a little blood escaped from the posterior inferior angle of the wound in the vein; after the insertion of an additional suture in the angle he hemorrhage ceased. The femoral artery had a fragment of tissue tornt off the side of its sheath, but the vessel wall was not injured. The bullet was not located. The vein wall was split by the bullet, no part of it being carried away, the usual result of a bullet wound of a vein. There was not a drop of blood escaping from either of the veins when the compresses were finally removed. The field of operation was sponged out with a five-per-cent. solution of carbolic acid, the wound closed, and the leg elevated. No drainage.

Fig. 15.—Shows Point of Perforation of Internal Saphenous and Femoral Veins.

The greatest difficulty in the operation was experienced in exposing the posterior surface of the common femoral vein on account of the close relation of the wound to the vena profunda.

The patient's temperature began to rise after the operation and on October 8th had reached 104° F. The wound was opened and a gauze drain inserted. The temperature gradually dropped and by October 12th was below 100° F., and remained below 100° F. until November 6th, when it reached 101° F.; November 7th in the morning, 102.2° F. The wound had been suppurating all the time, although the external opening was almost closed. On the morning of November 7th there was considerable hemorrhage, which was believed to be due to suppuration of the sutures in the vein. On November 8th the temperature was 102° F.; pulse, 130; more bleeding. On November 9th the pulse was 144; temperature, 100° F.; patient was coughing and expectorating a bloody mucus. On November 10th I saw the patient for the first time in a week; his temperature was then 101.6° F., and his pulse 104. Examination revealed a large swelling of the upper third of the thigh; the tension of the tumor was very great; blood was oozing from the small opening which still remained, and a dark clot could be seen inside the opening. There was no pulsation in the swelling. It was not auscultated. Patient was anæsthetized, the opening was enlarged, a clot four inches in diameter was shelled out, and in the bottom bright arterial blood flowed per saltum into the wound; digital compression controlled it until the field was entirely cleared. The inner side of the femoral artery for one inch was eroded and had a number of perforations. It was carefully dissected out, about one and one-half inches were resected, a single ligature was placed on the distal and a double

one on the proximal end. The cavity was cleansed and drained. The femoral vein could not be located. Some fragments of the femur which had been broken off by the bullet were removed.

Since November 27th the patient has been doing very well. There has been no disturbance of the circulation of the leg, and the cavity is almost closed. December 8th, there is a very small sinus remaining; patient is in excellent condition. The infection was probably produced by the bullet and the continued suppuration favored by the fragments of bone. January 4, 1897, patient completely recovered; no œdema, and no disturbance of circulation of leg.

Case II.—H. V——, Italian, peddler, aged twenty-nine. Referred to me by Dr. F. S. Hartmann, who assisted me in the operation. He was shot at eleven o'clock September 19th, and was brought to the hospital two hours later.

Clinical history: The patient was shot twice, one bullet passing into the abdominal wall just above the greater curvature of the stomach without penetrating the abdomen; the other entered Scarpa's triangle below Poupart's ligament. There was no bruit at this point or increased pulsation noticed at the time the patient was admitted to the hospital. I saw the patient first October 4th; examination revealed a loud bruit; it could be heard with the ear placed six inches from the thigh. There was no tumor and but slight increase in pulsation. The pulsation in the popliteal, dorsalis pedis, and posterior tibial arteries was scarcely perceptible. I examined the case again on October 6th and demonstrated it to a class of students. A thrill could be felt and a bruit could be heard. The latter was the loudest to which I had ever listened. The pulsation, though very feeble, could now be felt in the dorsalis pedis, but not in the posterior tibial.

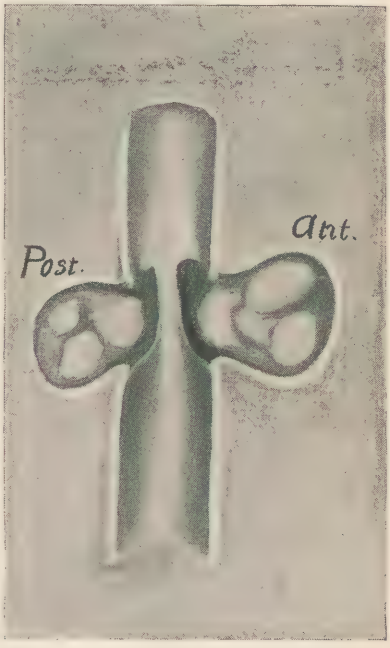

Fig. 16.—Shows Aneurismal Pockets on Anterior and Posterior Surfaces of Femoral Artery. Case II.

Diagnosis: Penetrating wound of the common femoral artery about one and one-half inches below Poupart's ligament. It was decided to cut down and expose the artery, and if a penetrating wound of more than one-half of the circumference was found to make a resection and unite it end to end.

Operation, October 7, 1896. An incision five inches long was made from Poupart's ligament along the course of the femoral artery. The artery was readily exposed about one inch below Poupart's ligament; it was separated from its sheath and a provisional ligature thrown around it but not tied. A careful dissection was then made down along the wall of the vessel to the pulsating clot. The artery was exposed one inch below that point and a ligature thrown around it but not tied; a careful dissection was made upward to the point of the clot. The artery was then closed above and below with gentle compression clamps and was elevated, at which time there was profuse hemorrhage from an opening in the vein. A cavity, about the size of a fil-

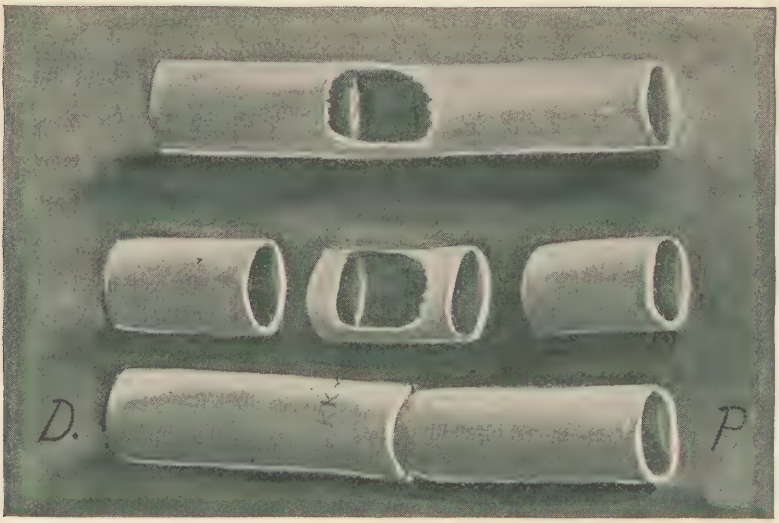

Fig. 17.—Shows Degree of Destruction, Portion Resected, and Appearance after Invagination of Femoral Artery in Case II.

bert, was found posterior to the artery communicating with its calibre, the aneurismal pocket. A small aneurismal sac about the same size was found on the anterior surface of the artery over the point of perforation (Fig. 16). The hemorrhage from the vein was very profuse and was controlled by digital compression. It was found that one-eighth of an inch of the arterial wall on the outer side of the opening remained, and on the inner side of the perforation only a band of one-sixteenth of an inch of the adventitia was intact (Fig. 17). The bullet had passed through the centre of the artery, carried away all its wall except the strands described above, and passed downward and backward, making a large hole in the vein in its posterior and external side just above the junction of the vena profunda (Fig. 18). Great difficulty was experienced in controlling the hemorrhage from the vein. After dissecting the vein above and below the point of laceration and placing a temporary ligature on the vena profunda, the hemorrhage was controlled so that the vein could be sutured. At the point of suture the vein was greatly diminished in size, but when the clamps were removed it dilated about one-third the normal diameter, or one-third the diameter of the vein above and below. There was no bleeding from the vein when the clamps were removed. Our attention was then turned to the artery. Two inches of it had been exposed and freed from all surroundings. The opening in the artery was three-eighths of an inch

Fig. 18.—Shows Position of Perforation of Femoral Artery and Vein in Case II.

in length; one-half inch was resected and the proximal end was invaginated into the distal for one-third of an inch with four double-needled threads which penetrated all the walls of the artery, as shown in Fig. 17. The adventitia was peeled off the invaginated portion for a distance of one-third of an inch; a row of sutures was placed around the edge of the overlapping distal end, the sutures penetrating only the media of the proximal portion; the adventitia was then drawn over the line of union and sutured. The clamps were removed. Not a drop of blood escaped at the line of suture. Pulsation was immediately restored in the artery below the line of approximation, and it could be felt feebly in the posterior tibial and dorsalis pedis. The sheath and connective tissue around the artery were then approximated at the position of suture with catgut, so as to support the wall of the artery. The

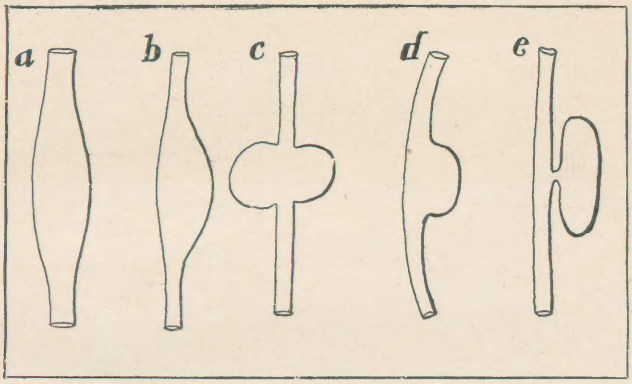

FIG. 19.—Shows Various Forms of Aneurism.

whole cavity was washed out with a five-per-cent. solution of carbolic acid and the edges of the wound were accurately approximated with silkworm-gut sutures. No drainage.

The time for the operation was approximately two and one-half hours, most of that time being consumed in suturing the vein. The artery was easily secured and sutured, and the hemorrhage from it readily controlled. The patient was placed in bed, with the leg elevated and wrapped in cotton.

A pulsation could be felt in the dorsalis pedis on October 11th, four days after the operation. There were no œdema of the leg and no pain. The circulation was good continuously from the time of operation. The wound suppurated; drainage was inserted, but at no time did the patient's temperature exceed 100.8° F. December 8, 1896, the circulation is perfect, the wound has healed with the exception of a small superficial ulcer, one-third of an inch in diameter. The patient has not had an unpleasant symptom since the operation. January 4th, patient is walking about the ward of the hospital, has no œdema and no disturbance of the circulation. January 10th, patient discharged from hospital recovered.

I desire to thank Dr. W. A. Evans for the microscopical work, and Dr. E. H. Lee for assistance in the experiments.

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